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Rainfall Analysis and Variation over Ecological Zones in Nigeria

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ABSTRACT: The trends of rainfall have a great impact on the hydrologic cycle, and therefore affect both the quality and quantity of water, and also reveal the effect of rainfall variability in the occurrence of drought and flood. This study analyses the pattern of rainfall and the variations over the Ecological zones in Nigeria. The monthly precipitation data for Nigeria for a period of 115 years (1901-2015) produced by the Climatic Research Unit (CRU) of University of East Anglia (UEA), Norwich, United Kingdom, and also year 2015 daily rainfall data from fifteen (15) Weather observation stations across Ecological zones in Nigeria were used. Weather observation stations were grouped into five Ecological zones based on their locations. Statistical tools were employed to analyze the data. The analysis showed that the mean annual rainfall for 115 years was 1164.91mm with the mean monthly maximum value of 228.8mm in August. The data was then grouped into decades; we observed that 1951-1960 had the mean maximum rainfall of 1237.68mm, while 2011-2015 had the minimum of 1014.18mm showing the evidence of erratic decrease in the number of rain-days in this present decade due to climatic change. However, the weather stations data showed that the mean annual rainfall was 3787.7mm in Humid forest, 1270.9mm in Derived savanna, 1141.5mm in Guinea savannah, 823.4mm in Sudan savannah and 559.3mm in Sahel savannah. In addition, the number of rain-days (rain >0.1mm) per year and mean rain per rain-day were calculated. Although, there is a general decrease in rainfall in Nigeria, the coastal areas in the Humid forest zone were observed to be experiencing slightly increasing rainfall in recent times.

KEYWORDS: Rainfall, Rain-days, Ecological zones

I. INTRODUCTION

Nigeria is a country located in West Africa along the Atlantic Ocean's Gulf of Guinea. Like the rest of West Africa and other tropical lands, Nigeria has only two seasons, the dry season and the rainy season. The rainy season is heavily influenced by an air mass originating from the South Atlantic Ocean, known as the Tropical Maritime (MT) air mass. Rainfall is the key climatic variable and there is a marked difference between the wet and dry seasons in most areas.

Previous studies have analyzed rainfall trends over entire or part of Nigeria: T.M. Hess et al (1995), reported that the North East Arid Zone of Nigeria experienced a significant decline in annual rainfall over the period 1961-1990, with an average trend of 8mm per year, and that this is a result of decrease in the number of rain-days per year. Oguntunde et al. (2011) analyzed rainfall trend over Nigeria using 1901-2002 rainfall data from Global Gridded Climatology of Climate Research Unit Time series (CRUTS.2.1). They concluded that annual rainfall has been reduced significantly, over 20% of the landscape and the amount of annual rainfall reduced by 50-350 mm in 64% portion of Nigeria. According to Akpodiogaga & Odjugo (2010), rainfall trend in Nigeria between 1901 and 2005 shows general decline. Within this period, rainfall amount in Nigeria dropped by 81 mm. Odjugo (2005, 2007) also observed that the number of rainy days dropped by 53% in northeastern Nigeria and 14% in the Niger Delta coastal areas. Besides the short dry season, August Break is being experienced more in July as against its normal occurrence in the month of August prior to the 1970s. This was attributed to major disruptions in climate patterns in Nigeria showing evidences of climatic change.

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The cause of rainfall fluctuations in many part of the country is generally attributed to large-scale pattern of atmospheric circulation. However, it may be that local land surface processes i.e. change in albedo, evapotranspiration, surface temperatures and atmospheric dust intensify drought result in dry periods lasting for longer than would occur. So also, a decline in total annual rainfall could arise from decrease in rain per rain-day, a decrease in number of rain-days within the season, a decrease in season duration or a combination of the three. Evidences like the increase in temperature, extreme weather events, incessant floods in the coastal region, drought in the north and increased health risks showed that Nigeria is already being plagued with diverse ecological problems which have been directly linked to the on-going climate change.

II. DATA COLLECTION AND ANALYSIS

The monthly precipitation data for Nigeria, produced by the Climatic Research Unit (CRU) of University of East Anglia (UEA), Norwich, United Kingdom for the period of 1901- 2015, and also the year 2015 daily rainfall data from fifteen (15) weather observation stations in Nigeria were used to analyze rainfall variability in Nigeria and across the Ecological zones. The monthly mean for the CRU data was calculated to show the mean monthly rainfall in Nigeria for 115 years. Also, the annual rainfall for the data was calculated to show the annual variability for the whole data over the period of 115 years. The data was then grouped into decades, with the last five years analyzed alongside. The monthly and annual mean were calculated and analyzed for each decade.

For the year 2015 rainfall data from 15 observation stations in Nigeria, the obtained data were in daily values from which monthly and the annual totals were calculated. Weather observation stations were then grouped into five Ecological zones based on their locations, with three stations each representing the Ecological zones. Sahel Savannah is represented by Katsina ($13^{\circ}0'N$ $7^{\circ}36'E$), Nguru ($12^{\circ}56'N$ $10^{\circ}29'E$) and Maiduguri ($11^{\circ}50'N$ $13^{\circ}9'E$) stations. Sudan Savannah is represented by Kano ($12^{\circ}02'N$ $8^{\circ}30'E$), Potiskum ($11^{\circ}39'N$ $11^{\circ}2'E$), and Yelwa ($10^{\circ}50'N$ $4^{\circ}44'E$) stations. Guinea Savannah is represented by Bida ($9^{\circ}3'N$ $5^{\circ}58'E$), Gombe ($1^{\circ}19'N$ $11^{\circ}2'E$), and Zaria ($11^{\circ}0'N$ $7^{\circ}40'E$) stations. Derived Savannah is represented by Lafia ($8^{\circ}30'N$ $8^{\circ}34'E$), Lokoja ($7^{\circ}47'N$ $6^{\circ}45'E$), and Oshogbo ($7^{\circ}48'N$ $4^{\circ}37'E$) stations. Humid Forest is represented by Calabar ($4^{\circ}57'E$ $8^{\circ}20'E$), Eket ($4^{\circ}38'N$ $7^{\circ}56'E$) and Warri ($5^{\circ}30'N$ $5^{\circ}41'E$) stations. The number of rain-day, mean rain per rain-day, annual maximum rain and total annual rainfall were determined. The number of rain-day per year was the number of days of the year with a rainfall amount greater than 0.1 mm.

III. RESULTS AND DISCUSSIONS

3.1 Mean monthly rainfall variability

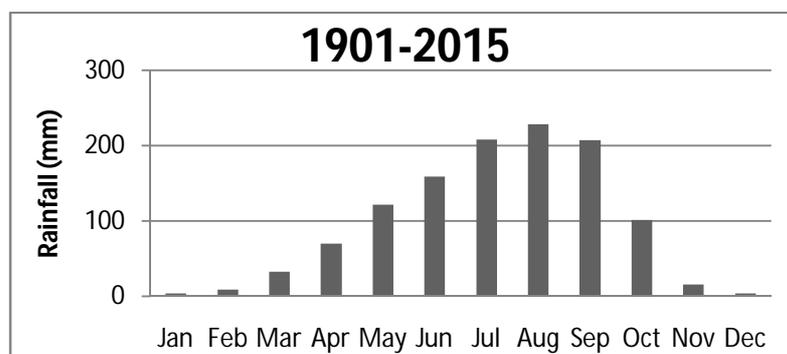


Figure 1. Mean monthly rainfall. 1901-2015

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The figure 1 above shows the mean monthly rainfall for the period of 1901-2015. The mean annual rainfall for 115 years was 1164.91mm with the maximum mean monthly value of 228.8mm in August. The minimum rainfall is shown to be in December with the mean monthly value of 4.26mm. The rainfall increases gradually from January till it reaches its peak in August, and then sharply decreases for the next three months till it reaches the minimum in December. The analysis showed 10.36% decrease in mean monthly rainfall from 1901-2015

3.2 Decadal mean monthly rainfall variability

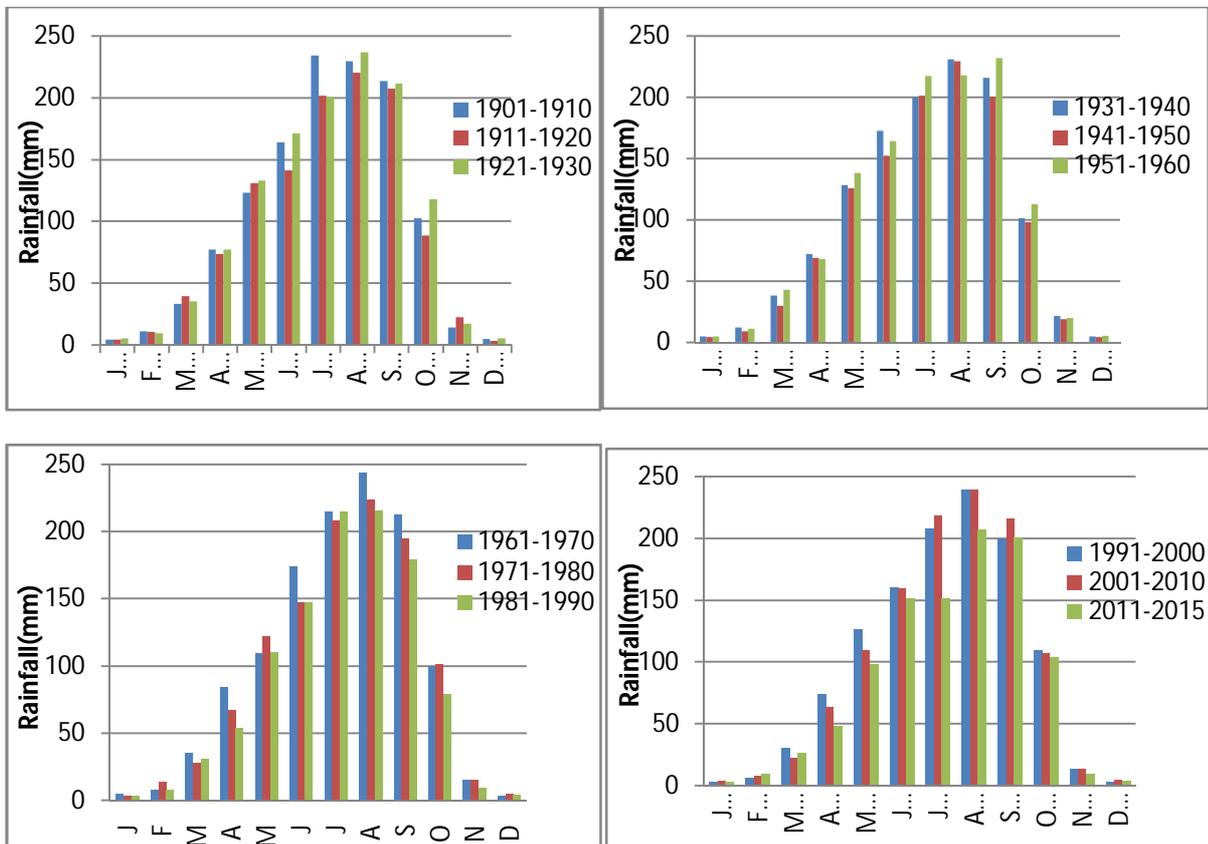


Figure 2: The decadal monthly rainfall variability.

The same pattern was observed for all the decades as shown in the figures, i.e. the gradual increase in rainfall from January till it gets to the peak in August, except for the two decades of the year in review. 1901-1910 had its mean monthly maximum of 234.05mm in July while 1951-1960 had its mean monthly maximum of 232.11mm in September. There is a clear evidence of decadal decrease in rainfall, the decline of 13% in July, followed by 12% in December, 11% in April 5% in February, and 3% in April and September respectively.

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3.3 Annual and Decadal mean rainfall variability

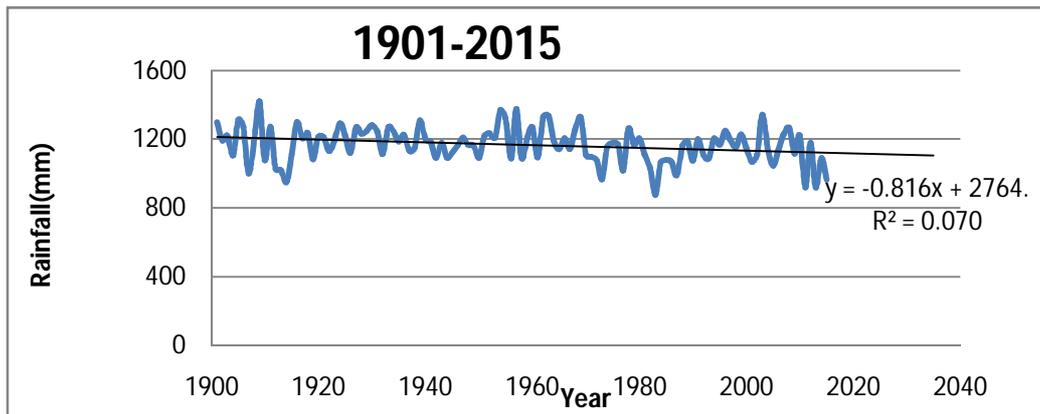


Fig. 3a

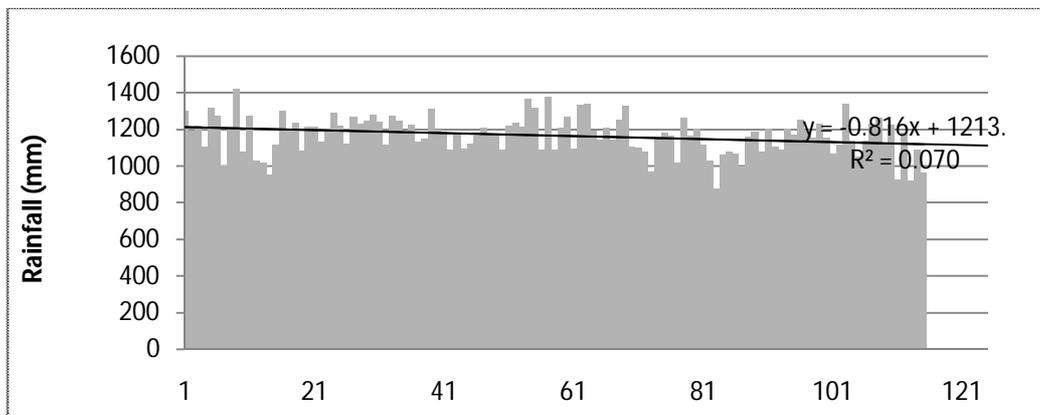


Fig. 3b. Annual rainfall

From Fig.3a and fig.3b, the highest rainfall was recorded in 1909 with annual rainfall of 1419.30mm. Other years of significant high rains are 1957(1375.75mm), 1954(1368.89mm), 2003(1341.31mm), 1963(1336.62mm), 1962(1332.08mm), 1969(1327.21) while lowest rainfall was recorded in 1983(875.69mm), followed by 2013(919.19mm), 2011(919.74mm), 1914(948.2mm), 2015(964.64mm), 1973(966.18mm), 1987(990.71mm). The trendline shows the decrease in rainfall for the whole period, with the slope $m = -0.8163$ and $R^2 = 0.0703$. The Rainfall in Nigeria between 1901 and 2015 shows a general decline (Fig 3a&b). Within the 115 years, rainfall amount in Nigeria dropped by about 134mm. The period of drastic decline is observed to be this present decade.

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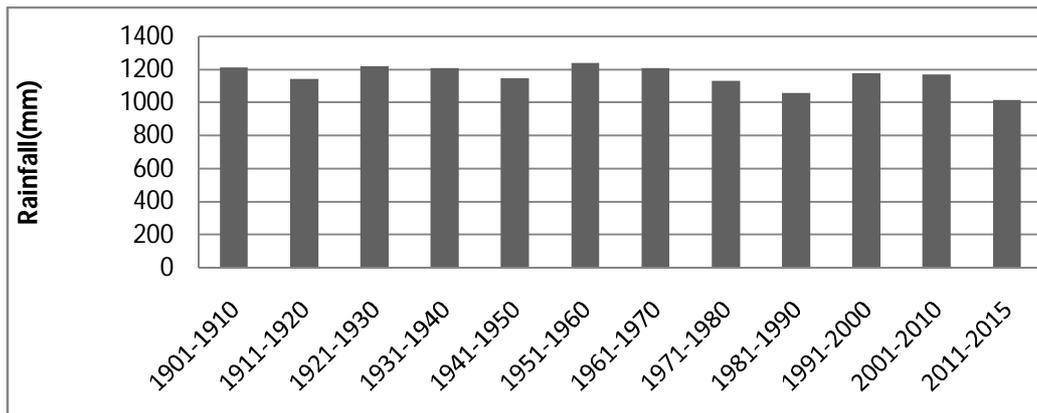


Fig. 3c. Decadal mean rainfall

For the decadal analysis in fig.3c, the highest rainfall of 1237.68mm was recorded in 1951-1960, then followed by a decline to 1205.03 (1961-1970), to 1127.76(1971-1980), and to 1055.29mm(1981-1990), and then an increase to 1174.01mm(1991-2000), then decreased to 1167.09mm(2001-2010) and finally to 1014.18mm(2011-2015) which is the lowest mean.

3.4 Rainfall variability over Ecological zone

Ecological Zone	Weather Stations	Number of Rain-day(mm)	Mean rain per Rain-day(mm)	Maximum Rainfall(mm)	Total Annual Rainfall (mm)
Sahel Savannah	Katsina	44	12.3	57.5	541.1
	Nguru	41	12.8	65.0	526.7
	Maiduguri	40	15.3	60.9	610.2
Sudan Savannah	Kano	42	19.8	182.4	830.1
	Potiskum	45	15.6	83.9	702.8
	Yelwa	62	15.1	70.9	937.2
Guinea Savannah	Zaria	72	15.6	61.7	1124.8
	Gombe	62	16.2	111.5	1007.0
	Bida	77	16.8	156.5	1292.7
Derived Savannah	Lokoja	69	18.8	96.0	1297.8
	Lafia	84	15.1	109.2	1266.0
	Oshogbo	100	12.5	71.2	1248.8
Humid Forest	Calabar	185	18.0	127.9	3330.8
	Eket	211	24.4	186.6	5157.6
	Warri	168	17.1	100.8	2874.6

Table 1. Number of rain-day per year, mean rain per rain-day, annual maximum rainfall and total annual rainfall for the stations representing each zone for the year 2015.

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According to Stern et al(1982), using the criteria for rainfall onset while their criteria for false start was not put into consideration, the rainfall onset day were Feb 3, Feb 7, Feb 16, March 24 and June 4 for Humid Forest, Derived Savannah, Guinea Savannah, Sudan Savannah and Sahel Savannah respectively.

From table 1 above, the decline and the variation in the amount of rainfall in Sahel, Sudan, Guinea and derived Savannah largely depend on the number of rain-day and partly on rain per rain-day. The mean annual rainfall in Coastal area of Humid Forest (3787.67mm) is about 6.8, 4.6, 3.3 and 3.0 multiples of Sahel (559.30mm), Sudan (823.37mm), Guinea(1141.50mm) and Derived Savannah (1270.87mm) mean respectively. The mean rain-day in the Coastal area is about 4.5, 3.8, 2.7, and 2.2 times the rain-days in Sahel, Sudan, Guinea and Derived Savannah respectively.

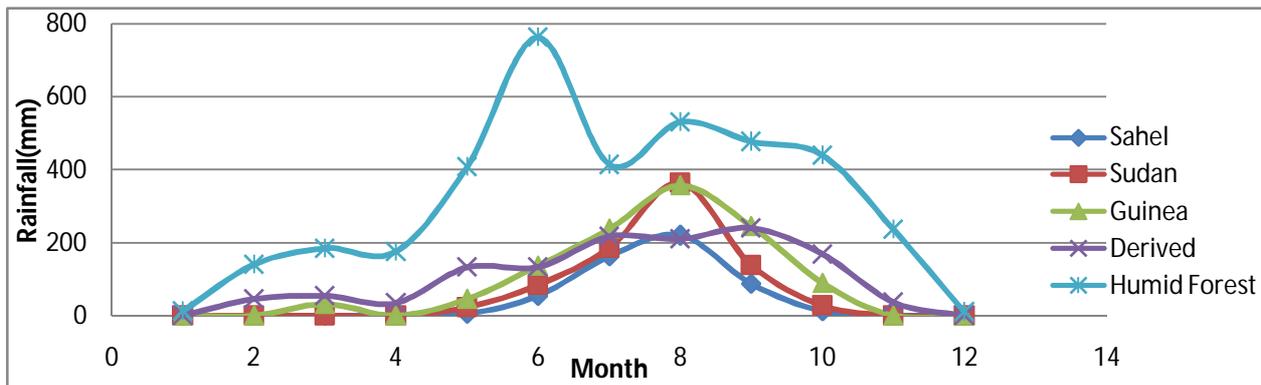


Figure 4a. Monthly Rainfall variability across Ecological zones in Nigeria(2015)

Figure 4b shows the monthly variation of rainfall in each ecological zone. It is observed that the Humid forest had the maximum monthly rainfall, with two peaks, first in June followed by sharp decline in July and then the next peak in August, before the gradual decrease in rainfall. In other zones, the peak is generally observed in August, except for Derived savannah with the peak in September for the year 2015

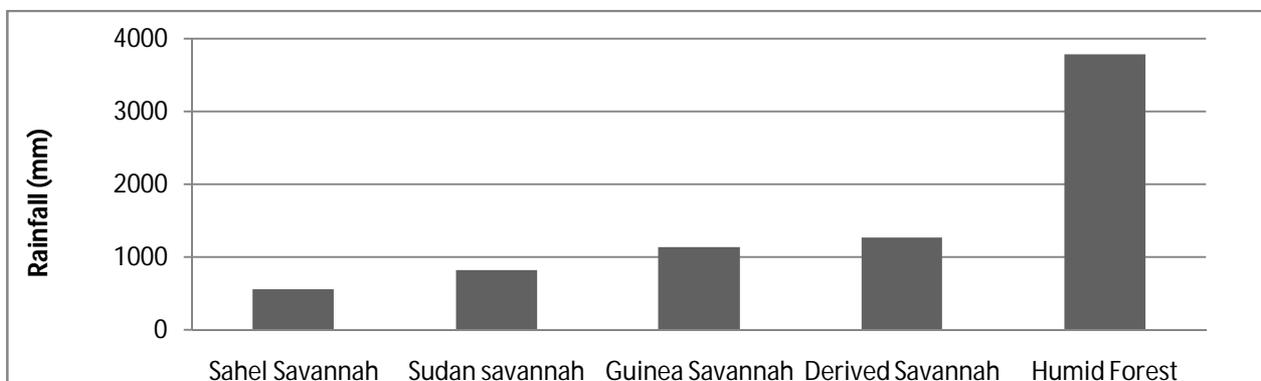


Figure 4b. Annual Rainfall variability across Ecological zones in Nigeria(2015)

From the figure 4b above for the year 2015, the mean annual rainfall was 3787.7mm in Humid forest 1270.9mm in Derived savanna, 1141.5mm in Guinea savannah, 823.4mm in Sudan savannah and 559.3mm in Sahel savannah.

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IV. CONCLUSION

This study aimed at analyzing the pattern of rainfall distribution in Nigeria over the period of 1901-2015. From the results, it was observed that the rainfall pattern was fluctuating and decreasing. The analysis showed 10.36% decrease in mean monthly rainfall and a clear evidence of decadal fluctuations with decrease in rainfall; decline of 13% in July, followed by 12% in December, 11% in April, 5% in February, and 3% in April and September respectively. This downward shift is clear evidence that Nigeria as a region is experiencing features of global warming and climate change.

Moreover, the variations in the Ecological zones in Nigeria for 2015 were analyzed. It was observed that the Humid forest had the maximum monthly rainfall. The peak is generally observed in August, except for Derived savannah with the peak in September for the year 2015. The amount of rainfall decreases with increasing distance from the coastal areas to the north, with Humid forest having the mean annual rainfall in multiples of other zones. The variation in the amount of rainfall largely depends on the number of rain-day and partly on rain per rain-day.

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